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In *Lampyris* the almost perpetual play of light, generated and partly confined within the posterior segments, has probably conduced to their final change of color. Ozone, of whose presence there is a suspicion, possibly exercises its bleaching power here as in vegetable tissues.

Assuming that the phosphorescent material is accumulated in the larval and preserved in the pupal stage for the final form, there are certain ways in which it might be useful at this latter period. The apterous female, being without food, must generate sufficient heat, from internal resources, to sustain life through oviposition.

The winged species may also utilize this power to decoy victims, and also to betray their presence to the carnivorous species, while others may kindle the torch of Hymen by this veritable flame. That both sexes possess phosphorescent properties is not surprising, since both are the product of a luminous stock, but we may expect a greater degree of phosphorescence from the female, and facts sustain this expectation.

Thus our insect seems eminently conservative in its powers, while combining the useful and the beautiful in its physical gifts.

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PHYSIOGRAPHY.

BY C. LLOYD MORGAN, F.G.S., A.R.S.M.

THE artist who is illustrating a great theme upon a large spread of canvas finds it necessary from time to time to lay down the brush, with which he is accurately filling in the more delicate minutiæ, that he may retreat to a distance and view his picture as a whole. It is essential to the higher development of his art that he should not omit this comprehensive survey. The same thing holds good in literature and science, as well as in art. The historian must, from time to time, take a fresh survey of history as a whole. If he neglect to do so, the group of figures to which he devotes his special attention will certainly not take up its true position among the other groups that appear on the canvas of history. The man of science, also, should not forget that he is, according to his individual bent or capacity, aiding in the construction of a great philosophy; and he should now and again turn aside from the microscope, or lay down the hammer, to take a more comprehensive survey of that philosophy, whose aim it is to comprehend and consolidate the widest generalization of science.

A rude attempt at such a survey of the principles of geology and the bordering branches of science will be found in the following pages. They are from the notes of a lecture which formed the last of a course delivered before a school audience. In that lecture I did my best to give a rough sketch of that chain of events by the study of which we may build up a history of the Earth, while I endeavored at the same time to lead my hearers upwards from the simple to the complex ; for I hold that the teacher of science should lead his pupils from the well known, through the less known, to the unknown. Taking a few simple and obvious facts as a basis, he should first test whether those whom he teaches really know them to be facts, and then, carefully building upwards, seeing that each stone of his superstructure rests securely on one which has before been firmly laid down in its true place, he should mount slowly and surely, until, at last, he reaches that rare atmosphere of the unknown in which, for the present at least, no man may build.

Standing by the sea-side, then, let us inquire of Nature concerning the things which we see around us. The waves roll in upon the shore, the wind blows freshly in our faces, a heavy storm-cloud hangs over the distant horizon, at our feet is a little streamlet running over the sands to the sea ; behind us is the white chalk cliff, capped with sand and clay.

How come these waves, and what are they doing? shall be our first question. The answer to the first part of the question is so obvious that a child will not hesitate to reply, that it is the wind which produces the waves. At first a mere cat's paw on the surface of the sea, the growing ripples are, as the wind continues, hurried onwards, increasing both in length and breadth, and, where the water is deep, in velocity of motion, until they become the great waves, some fourteen feet high from trough to crest, which we see on our coast during a storm, and finally, if they have a fair field, develop into ocean billows, twenty-six feet high in the Atlantic, forty feet high in the Southern Ocean. In the open sea the water is not carried forward by this wave motion. We may watch the sea-bird rise and fall as the wave passes under her. She is not carried forward on its summit. But when the wave reaches shoal-water, in the neighborhood of land, the lower part is retarded by friction against the bottom, while the upper part hurries on, and the wave breaks, and rushes up the shore, the under water racing back and tearing up the beach in its backward course. It is in this way that the sea has such power in grinding down the rocky materials which fall to the base of our island cliffs. Along the Chesil Beach the pebbles are carried forward fifteen miles by the action of the waves, and as they grind over each other in their westward course, they become smaller and smaller.

Here then we obtain an answer to the second part of our question: What are the waves doing? They are beating backwards and forwards the matter which falls from the cliffs, until it is broken up and rolled into a rounded pebbly beach. But they are doing more than this. They are battering at the cliff itself, and aided by rain, and frost, and wind, are eating away our island shores. The force with which the waves dash against the cliffs is at times enormous, having been known to reach a pressure of more than three tons on the square foot. During the hurricane which swept over Barbardoes in 1780, cannon which had long been lying sunk were washed far up on the shore.

In some parts of England the sea is advancing rapidly on the land. Prof. Huxley, in his excellent little book on Physiography,[1] quotes, as an instance, the fact that Reculver church, which in the time of Henry VIII, was a mile from the sea, is now only preserved from the destructive action of the waves by a stone breakwater made by the Trinity Board. Not long ago, I walked along the coast from Herne Bay to the Reculvers. The rapidity of the waste was clear. In many places portions of the path had been carried away. Masses of grass-covered earth, lying at the foot of the vertical portion of the cliff, showed how recent had been the precipitation from above; while the clean-cut face of the cliff, and the sharp forms of the projecting ridges and pinnacles of the clay showed that since they were left in their present position, they had not suffered for long the attacks of rain and wind. Great cracks at the surface, here and there, showed that destructive action was still in progress; and when I looked at the lately fallen blocks of earth below, I felt that it was possible that the grass tufts, on which I stood, might be the next to fall amidst the

[1] 8vo. pp. 384, with 5 plates and 122 woodcuts (Macmillan & Co., London, 1878).

ruins beneath me. But though the action of the weather was thus clear, the sea-waves, which alone permitted that action to continue, were not idle. The brown color of the sea for some distance from the shore gave evidence of this, and while I stood upon the beach, I saw several projecting blocks of clay wasted by more than half.

In Scotland and Western England, where the rocks are hard, the advance of the sea upon the land is quite imperceptible. All the beauties of our coast scenery, our bold headlands and sweeping bays, result from this *unequal* action of the sea upon the harder and softer rocks of which our island is built up. But little observation is necessary to make it clear that, along any coast-line, the promontories are composed of hard rock, the bays of a softer material. Sea-side scenery is, therefore, a joint product of wave action and the geological structure of the coast. We must not forget, however, that it is only along its margin, where it beats upon the shore-line, that the sea is an agent of *denudation*. Throughout its great extent the ocean is the area of deposit and construction, just as the land is the area of destruction and waste. Beneath the sea the products of that waste come to rest. Strange as it sounds, the sea is the cradle of the land. Beneath the waters of the ocean are formed those layers of sediment which will some day be raised above the waters to form the framework of new continents.

From the answer to our first question, then, we learn that the waves are advancing upon the land, and thus producing our coast scenery, and that they are caused by the winds.

Let us next consider the streamlet at our feet. What is it doing, and how comes it here? That little streamlet, if we will but listen to it, can tell us much about what the great rivers of the earth are doing. Let us learn from it. In the first place, then, we see that this miniature river[1] is gradually changing its course. The main current strikes against one bank more than the other. The result is that this bank is forced to recede. Its tiny cliffs are undermined by the action of the stream, and the upper portions, now and again, topple over with a little splash into the water. Here we have in miniature that which may be seen on an enormous scale on the Mississippi and the Amazons. Large vessels may there be made to rock by the waves created by the fall of great masses of the concave bank, the river having in this way advanced upon the land hundreds of yards, and, in some cases, even, several miles, within the memory of living men.

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[1] Miniature Physical Geology, *Nature*, March 8, 1877.

This shows how a stream cuts its way *sideways* into the land. This is not, however, the most important part of what a river does. If we follow our stream a little way inland, we shall discover that it cuts its way *downwards* and cuts it way *backwards*. Both modes of action go on, as a rule, at the same time ; but sometimes one, sometimes the other, is most obvious. Of the first, the Cañon of the Colorado offers an example on the grandest scale. This great ravine is about three hundred miles long and, in places, *more than a mile* deep. There can be no doubt that it has been entirely cut down into the desert plateau by the action of the river. How this was effected we learn, to some extent, from the following sentence in the American report on the river, "The water of the Colorado," says the reporter, "holds in suspension a large amount of fine siliceous sand, sharp as emery, that eats away the valves" (connected with the machinery of the steamer) "as rapidly as it could be done with a file." It has probably been with the aid of this sand that the river has cut down its deep trench.

Of a river cutting its way backwards, the Niagara is the grandest example. At the Falls the water tumbles over a ledge of limestone which rests on a thickness of shales. By the action of the spray which rises from the waterfall, and partly by the power of frost, the shale is rotted away, and thus the limestone is undermined. It is in part owing to the undermining action, that visitors can proceed a little way under the Falls. To do so is well worth a wetting; a whole river takes its mighty leap, and falls with a bewildering roar at your very feet, and if it be winter giant icicles hang above your head. When the "under-cutting" has gone on for a certain time, huge blocks of the limestone tumble with a crash to the base of the waterfall. In this way the Falls of Niagara are working backwards, at the rate of about one foot a year, towards Lake Erie. Only the other day it was stated in *Nature* that, on November 17, 1877, a large section of the rock towards the Canada shore fell with a tremendous crash, and that during the night a still larger area went down.

But what becomes of all the material dug out by the stream as it cuts its way sideways, or downwards, or backwards? If we watch any little rill which falls into a pool on the sea-shore, we shall soon find out. We shall see that the sand and other material which it carries are built up into a little delta, while some of the finest material is spread at large over the bottom of the pool. Large rivers carry vast quantities of mud and sand and silt (much of which is washed off the land by the rain) to the sea. Experiments of mine on the Thames, at Surbiton, show that in fine weather, when the river was low and fairly clear, solid matter in suspension was being carried seawards at the rate of 9767 tons per annum; while, when the river was in extreme flood, matter at the rate of 524,940 tons per annum was passing in this way down towards the sea. With the great rivers of the world of course the amounts are still more enormous. Sir Charles Lyell calculated "that if a fleet of more than eighty Indiamen, each freighted with about 1,400 tons weight of mud, were to sail down the Ganges every hour of every day and night for four months continuously, they would only transport from the higher country to the sea a mass of solid matter equal to that borne down by the Ganges in the four months of flood season." All the matter carried down in this way is built up, layer upon layer, into a vast delta deposit, or strewn over the bed of the ocean. Of such layers much of the crust of the earth, the sand and clay at the top of the cliff behind us for example, is composed.

But besides the matter carried down by rivers in suspension, a vast amount is carried down in solution. Take the Thames for example. For every grain transported mechanically, more than twenty grains are carried down chemically. Every gallon contains some twenty grains of lime salts, and about two grains of common table salt, or chloride of sodium. These also are carried out into the sea, in which the chloride of sodium, along with certain other salts, accumulates on the evaporation of the water, and thus forms the brine of the ocean, while the carbonate of calcium is separated by living creatures and built up into some sort of pure limestone. Of such limestones also much of the crust of the earth, the chalk of the cliff behind us for example, is composed.

We have thus seen what the streamlet is doing. It is aiding the rivers of the world to carve out valleys, and it is carrying seawards the fine mud and sand which result from its own work and that of rain, to contribute to the framework of a future continent.

And how comes it here? Directly or indirectly from rainfall. Whether its source be a spring, or the collected waters from a sloping hill-side, it matters not. Without rainfall, such as is now pouring from the distant storm-cloud, the streamlet could have had no existence.

Another question therefore suggests itself: What is this rainfall doing, and how comes it here? If we walk along the shore for a little distance, we may perhaps see (if there is beneath the cliffs any clayey material containing flat stones) small pillars of earth, each capped by one of these flat stones. These are little monuments of rain action. Rain falls upon the surface and runs off towards lower levels; as it runs, however, it carries with it a little of the fine clayey material. Thus it lowers the surface. But where there is a flat stone, the surface is protected from the softening action of raindrops, just as a house is protected by its roof. The soil beneath the stone is not carried away, and the miniature earth pillar stands out as a monument. In Switzerland there are, in several places, earth pillars fifty or sixty feet high, which have been formed in this way.

But it is not only where there are earth pillars that the rain is exercising a denuding action upon the land. If we go out into the fields on any rainy day, we may watch how the soil is literally flowing downwards to the sea. Few fields are perfectly flat, and the rain which falls upon the surface tends to drain off at the lowest possible level. But if we examine the water which is thus on its way down the field, we shall at once see that it is not clear, that it carries with it some of the soil. Much of the rain, of course, sinks into the ground. But before it does so it is nearly sure to trickle a foot or two over the surface. Even if it only runs a few inches, it must bear with it some of the soil for this distance, and there leave it. If the rainfall continue, the soil is soon carried a few inches further; and it always travels in one direction from higher to lower levels. Our field may be separated at its lower end from another by a wall, which will check the downward progress of the soil. If this be so, we shall often find that, from the accumulation of this soil, a child may look over the wall on that side of it which faces up hill, while a full-grown man may have to stand on tiptoe to gain the same advantage on the lower side. Or perhaps at the bottom of the field there may be a ditch; that ditch may communicate with a streamlet, and the streamlet fall into a river. Some of the soil of the field is thus carried by every heavy shower of rain into the ditch, and thence into the river. After a wet day we shall find that all the tiny rills, the little rivulets, the streams, and the great rivers themselves, are muddy and thick. This mud is nearly all derived from the soil of the land which lies in the river-valley. Thus the land is always flowing downwards to the sea; not a particle can get up again when once it has flowed even a few feet in its downward course; and this action is going on wherever rain falls upon the surface of the land.

But though the surface layer is, in this way, being constantly washed off the fields, the soil does not lessen in quantity. For as fast as material is carried away by the rain, so fast does the same agent, aided by weathering action, prepare fresh soil, to be treated in a similar manner. At the same time we must remember that, though the amount of soil does not grow less, the amount of land above the waters of the ocean does diminish. Does this seem strange? A rough analogy may serve to make it clear. A man possesses a certain amount of money, most of which is in the bank, and a small amount for immediate use in his waistcoat pocket. As fast as his ready cash disappears he draws a check on his banker, and in this way his waistcoat pocket has a more or less constant supply. Practically speaking, therefore, his ready cash does not diminish, though his balance at the bankers does not remain equally constant, but decreases day by day, at a rate which would shortly lead to bankruptcy if he were not careful that there should be a supply equal to the demand. Now the soil is the ready cash, and the strata of England the balance at the bank. Rainfall is continually tending to diminish the amount of soil or ready cash, which is made good by a fresh supply from the bank. It is perfectly obvious, however, that the balance at the bankers must decrease, and that in the course of ages England must be entirely washed away into the sea of geological bankruptcy unless the bank receive a fresh supply; unless, in other words, by the force of elevation, fresh land be raised from time to time above the waters of the ocean.

With regard to the influence of rain on the physical aspect of a country, it may be said that viewed on a large scale and in a general way, this agent exercises a softening effect on scenery; in those areas where the strata are of a soft and easily yielding nature, the work of rain as an earth-sculptor is to cause the land to assume a gently undulating form, and to extend in *breadth* those valleys which rivers are always tending to extend in *depth.* On those rocks, however, which are of a harder nature, rain has less absolute power, but even here it renders the scenery less rugged; less sublime perhaps, but more beautiful.

And how comes this rain? We know that it falls from the clouds. We know too that these clouds are formed when the air above is cooled so much that it can no longer hold in solution all the vapor of water which it has borne in an invisible form from afar. The rain, therefore, comes from the vapor of water existing in the wind. And how comes it to exist in the wind? It is obtained from the Atlantic Ocean. Thither then we must travel in thought and try and picture to ourselves what takes place when the visible liquid water is converted into the invisible gaseous vapor of water. Now it is quite evident that some force is overcome—some binding force which drew the particles of water closely together. This force is cohesion. It may be likened to a strong man who holds the watery particles in bondage, not indeed so severe as that of the terrible ice-king of the Arctic and Antarctic regions, for they are allowed free motion among each other and are not locked in the solid state, but still *bondage* chaining them down to the limits of the ocean. This strong man will not loose his grip until he be conquered by a stronger than he; and on the Atlantic he meets with that stronger man whom we call heat.

Sun-heat sets free the particles of water from the bondage of cohesion, and allows them to escape into the air. But the mastery is not gained without an effort, and the value of this effort has been calculated. To emancipate nine pounds weight of water particles, an amount of energy has to be expended, equal to that of lifting a ton to the top of a precipice 2900 feet high.[1] But just as, when two wrestlers struggle together, neither can master the other without a true waste of his substance taking place, a waste that has ere long to be made good by the absorption of a certain amount of mutton or beef, so too on the Atlantic, during the struggle between cohesion and heat, a certain amount of the latter is consumed and disappears. The amount of heat so expended has also been calculated. In setting free nine pounds of water particles an amount of heat disappears sufficient to fuse forty-five pounds of cast iron.[1]

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[1] These are two different ways of stating the *same* fact.

To take leave of metaphor, this amount of heat is expended in overcoming cohesion and tearing asunder the particles of water. The vapor particles thus formed, kept separate from each other by heat, are carried by the wind to our shores; there the air in which they float is cooled; the heat is now insufficient to overcome the force of cohesion, and the water particles, no longer held apart, clash together, and as they do so they generate by the shock as much heat as was expended before in tearing them asunder. All the heat which disappeared—was rendered latent or hidden—when the vapor of water was raised from the Atlantic, is set free or rendered sensible when condensation takes place. For every nine pounds of weight of cloud formed in our skies, an amount of heat is set free sufficient to melt forty-five pounds of cast iron.

A valuable lesson may be learned from this behavior of water and water vapor. When the liquid water became gaseous vapor a certain amount of heat energy disappeared. But it was not destroyed. It was converted into another form of energy which we may call the energy of separation. The particles were forcibly *separated* from one another, and a certain amount of energy was necessary to keep them apart. Presently, however, they clashed together again and the energy of separation was reconverted into the energy of heat. The amount of heat given out was exactly equal to the amount of sun-heat absorbed. Day by day fresh experiment and observation make clearer this great law of nature: that by no means at our disposal can we either destroy or create energy. We may change it in a number of ways. We may convert chemical separation into electricity, this into mechanical motion, and mechanical motion into heat. But we can neither call into existence or put out of existence any portion of the energy of the universe, any more than we can call into existence or put out of existence any portion of the matter of the universe.

One more fact must be noticed. Though the same amount of heat is given out by the condensation of the aqueous vapor as was absorbed on the Atlantic during its formation, it is no longer useful in the same way. It does not possess the power of again converting water into water vapor. It has become degraded. It is the same in amount, but different in value. The water which turns a mill is the same in amount whether it lies above or below the water-wheel, but it differs vastly in value. That above the mill is useful to the miller, that below the mill is useless. It is the same with energy. Just as water tends to run down from higher to lower levels, so does energy tend to run down from higher to lower forms. All forms of energy tend to be degraded to heat uniformly diffused throughout space.

To the energy of sun-heat, then, we owe the existence of vapor of water in the wind. And to what do we owe the wind itself? To the same cause. On any winter's evening, the colder the better, we may make the following experiment, first performed by Franklin: When the dining-room is warm but the hall outside cold, we may throw open the door to its full extent. On holding a lighted candle in the doorway near the top, we shall find that the flame is blown outwards; on holding it near the bottom, we shall find that it is blown inwards; midway between the top and the floor the flame will burn steadily. The cause of this is obvious when we remember that warm air is lighter than cold air. When the door is opened warm air rushes out near the top, and to supply its place cold air rushes inwards along the floor. The two currents are divided by a calm.

At the seaside we may watch the same sort of experiment performed on a larger scale by nature. In settled summer weather sailors count on a sea-breeze in the morning, and a breeze from the land at night. The cause of these land and sea-breezes, with which every yachtsman is acquainted, is simple. In the morning the sun shines alike on land and sea, the land, however, most readily takes up the undulations of heat. The air above the land thus warmed expands, and forms an upward current, while a refreshing breeze comes along the surface from the sea, just as a cold current passed along the floor from the hall.

At nightfall the reverse is the case. The sun withdraws his rays from land and sea; but the land, which was the first to be heated in the morning, is the first to cool in the evening. Soon it is as cool as the sea. Ere long it has become colder than the sea. And the current now sets outwards from the land. We have changed the conditions. We have brought a refrigerator into the dining-room, and the lower cold current now sets outwards into the hall. It is, of course, under ordinary conditions, only the under current which we on the earth feel. The upper current is far above our heads. A French balloonist (Tissondier) rose from Calais into the upper current, and was carried far out to sea; on descending he entered the under current, which bore him safely back to Calais.

The same laws are seen in operation in the Indian Ocean. There for half the year the North-east Monsoon which blows *from* the continent of Asia is the prevalent wind. During the summer, however, it is forced back by a South-west wind, caused by the great upward draught over the glowing plains of Central Asia.

Far away on the broad Atlantic and Pacific Oceans, we may see the same thing on a scale so magnificent as to form a healthy and vigorous circulation for the whole world. In the great system of winds, of which the trade winds are the most constant, we have mighty currents of air which sweep from pole to pole, and are the very life of the earth over which they pursue their ceaseless course.

Thus the existence of the winds is due to sun-heat.[1]

Let us pause here for a moment to see what we have learnt. We have seen that the waves which beat on our shores, and denude our coast-lines, are due to the winds; that the rivers which cut down trenches into the earth are due to rain, which is itself brought to us as vapor of water by the winds; and we have seen that both the formation of water-vapor, and the existence of the winds, are due to sun-heat. This sun-heat is therefore the highest link we have yet reached in the chain of causation. We have also seen incidentally that the sand and clay at the top of the cliff were built up of mud and sand grains, carried down mechanically by rivers to the sea: and that the chalk has been separated by living creatures from the sea-water to which the lime had been carried down in solution by rivers. The question—how came this life upon the earth?—now arises. It will not however be discussed here. It is enough to state that it is almost universally believed by those competent to give an opinion, that all life forms have come into being by a process of evolution from primitive organic germs. It may be noticed, however, that all life, whether vegetable or animal, is made possible only by *solar energy*. Animals depend on plants, directly or indirectly, both for the food they eat and for the air they breathe. In the absence of sunlight plants would be unable to decompose the vast quantity of carbonic acid which animals breathe forth: and thus *their* source of carbon and our source of oxygen would be cut off.

Another question must now be put and shortly answered. The sand and clay and chalk which form our cliff were laid down beneath the sea; how come they now to form dry land? Now it is clear that one of two things must have taken place: either the level of the sea has been depressed or the land has been raised. Geologists do not hesitate to say that it is the land which has undergone the change in level, while the sea has remained stationary. The sea is, in fact, more stable, more constant, more ancient than our oldest continents. All land is, on the other hand, subject to changes of level. In the Himalaya mountains shells, which once lived in the sea, are found at an elevation of 16,000 feet above the level of the ocean. The northern part of Scandinavia is even now slowly rising, while the southern portion is undergoing depression. But how? There lies the question.

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[1] Their direction is modified by the rotation of the Earth.

It is now well known that the earth is, in the interior, in an intensely heated condition. In deep wells and mines the temperature rises about 1° Fah. for every sixty feet we descend. The melted lava poured forth during volcanic eruptions gives us some idea of the temperature comparatively near the surface. The centre of the earth must then be hot beyond conception. But it is gradually cooling. Heat is flowing outwards through the crust into space: the cooling of the earth is accompanied by contraction of the mass of the earth: and unequal contraction produces areas of depression and elevation.

Is this clear? Perhaps a comparison of great things with small will make it clearer. The human mind seems at times to fail to grasp facts which are, in truth, simple, but which from their magnitude are hard of conception. If, for instance, we stand on a high peak and look out over a portion of a great mountain chain, and see the grand summits standing out along the central ridge, it is difficult to conceive how this grand upheaval could have been produced; and perhaps the mind, wearied with the attempt to grapple with a subject almost too great for its powers, finds relief in the thought, that the mighty elevation was due to some great cataclysm or convulsion of nature, concerning the cause of which —as a matter beyond our ken—it would be rash to speculate. And if it were then suggested that mountain chains, such as that in the midst of which we were standing, must be the inevitable result of the contraction of a cooling globe, it may be that our understanding would reject a conclusion which it could not at once grasp.

But if when we have left the mountain top, we take up a withered apple of last year's growth, the consideration of its surface may help us to understand that which before was so hard to comprehend. When we plucked that apple, a year ago, its surface was smooth, and the skin was stretched tightly over the fruit beneath. But since that time the apple has shrunk in size, the fruit having contracted within the skin, which, no longer tight and glossy, is now wrinkled and puckered up.

But just as in the apple, so too in our planet, there is an inner portion which is contracting, and an outer portion which does not shrink: and as surely as the earth is losing heat by radiation into space, her mass contracting and her size growing less, so surely must the outer portion become puckered up, the most prominent wrinkles forming what we call mountain ranges.

While *sun-heat*, therefore, enables rain, rivers, and the sea to denude the land and to combine in the formation of new continents, *earth-heat* causes a fresh supply of land to be raised above the waters. Were it not for this earth-heat, England, as already, mentioned, would during the course of geological time be entirely washed into the ocean of geological bankruptcy. All geological action, except that due to the tides, is brought about by sun-heat or by earth-heat.

Before inquiring what is the cause of this sun-heat and this earth-heat, there is one more question to be answered. Of what does the air, the water, the cliff, ultimately consist? Are earth, air, and water, as the ancients believed, elements? No. The air is composed chiefly of a mixture of a gas called nitrogen with one-fifth of its volume of oxygen. It is not difficult, as will be seen in Professor Huxley's book, for the chemist in his laboratory to separate these two gases. Nor has he much difficulty in splitting up water into the two gases, oxygen and hydrogen; while the further task of ascertaining of what the solid crust of the earth is composed, though it requires more labor, is by no means beyond his powers. But whereas water contains but two elements, in the solid crust of the earth there are about sixty-five. But what are these elements? They are simple bodies which resist every effort of the chemist to decompose them into simpler bodies. Many chemists, however, believe that, though we cannot by any means at our disposal thus split them up, this is only because the means at our disposal are limited, and that, at an intensely high temperature, all would be found to consist of one primitive form of elementary matter.

One of the most striking results of modern scientific inquiry is the discovery, by means of the spectroscope, that there exists in the sun's photosphere some sixteen or seventeen at least of the so-called elements, with which we are acquainted on the surface of our earth. Herein lies one of those many bonds, by which we are connected with our central luminary. The cause of these bonds; the origin of sun-heat and earth-heat; and of the sun and the earth themselves, now require elucidation.

According to the now-generally-accepted theory, known as the Nebular Hypothesis of Kant and Laplace (and it must be noted that we are here passing from the well known to the less known), our solar system was formed from a diffuse nebulous mass. We must imagine that this rotating spheroid mass once extended to the furthest limits of the solar system, beyond the orbit of Neptune. It radiated heat freely into space, and under the force of gravitation underwent contraction. And as it contracted it left behind it rings of vapor which, breaking up, formed secondary rotating spheroids, themselves contracting, themselves leaving behind them rings, forming tertiary spheroids, themselves passing in their orbits round the central mass. That central spheroid mass is the sun; one of the secondary rotating spheroids is the earth, the moon being a tertiary spheroid. The earth-planet thus formed was gaseous; but as time rolled on, it passed through the liquid state, to the more or less solid state, which it at present possesses.

Sun-heat is therefore the result of the condensation of the primary spheroid: earth-heat the remnant of that produced by the condensation of a secondary nebulous spheroid.

And now comes the question, how was the rotating nebulous spheroid formed?

If we take a small piece of lead and deal it a number of heavy blows with a hammer, we shall find that the lead becomes hot. If we continue to hammer for ten minutes, we shall find that the lead becomes too hot to hold. Now what is the cause of the heating of the lead. Simply this: when the lead is struck, the motion of the hammer is suddenly stopped; but the motion is taken up in a new form by the particles of the lead, and this new form of motion is heat. The visible motion of the hammer is converted into the invisible molecular motion of heat; for heat is simply the rapid vibration of the ultimate particles of matter.

When a bullet is shot from a rifle against an iron target, the rapidity of the motion is suddenly arrested; heat is developed; and this heat may in some cases be sufficient to melt the point of the bullet. In the same way the immense iron shot, hurled from our modern pieces of ordnance, cannot fail to be intensely heated, when they strike against the sides of such a ship as the *Inflexible.* It is quite conceivable that a shot or bullet of lead might be projected with such violence as to be, not only fused, but converted into vapor on striking the target. For when the motion of heat becomes extremely violent, the particles of matter are shaken asunder, and a vapor is formed.

We may take the velocity of a rifle bullet to be 225 feet in a second. The velocity at which the earth moves through space, as she travels round the sun, is about nineteen miles in a second. If we imagine that the earth were suddenly to strike a huge target, the heat generated would be sufficient, not only to fuse the earth, but to reduce it in great part to vapor. "The amount of heat thus developed would be equal to that derived from the combustion of fourteen globes of coal, each equal to the earth in magnitude. And if, after the stoppage of her motion, the earth should fall into the sun, as it assuredly would, the amount of heat generated by the blow would be equal to that developed by the combustion of 5600 worlds of solid carbon."

Now, it is supposed by Dr. Croll and others (and here, be it noticed, we pass to the still less known; to the purely hypothetical, but still conceivable), that the nebulous mass from which the solar system has been evolved resulted from the collision in space of two vast masses moving at great velocity. Each of these masses may be supposed to have developed from a nebulous mass, in the same way that the solar system has itself developed. Such nebulous masses were endowed with that high form of energy, which may be termed, generally, the energy of separation. But we have seen that this and all other intermediate forms of energy tend to run down, and be degraded to heat uniformly distributed throughout space. Some men of science tell us that this will be the ultimate condition of the energy of the universe. They tell us that the planets will fall into the sun, and that thus the matter of the solar system will be aggregated into one mass, that this mass coming into collision with another mass similarly formed will produce the nebulous spheroid from which another system greater and grander than ours will be formed, and that so the same thing will go on until all the matter of the universe is aggregated into one mass, and all the energy of the universe is converted into uniformly diffused heat.

But here have transcended the powers of the human intellect. We have reached that thin atmosphere in which we can no longer build. We have traced the chain of causation as far as we are able. We have reached the Unknowable. When we seek to go further; when we inquire what is *matter*, what is *force*, what is the *ether* through which force acts on matter, what is the *space* in which co-existences are manifested, and the *time* in which sequences are manifested; when we inquire what is consciousness, what is the *thought* by which we are able to trace to some extent the chain of causation, we are met by alternative contradictories. We are in the presence of the Mystery of Mysteries. Let us humbly, modestly, truthfully confess our ignorance.

It may, perhaps, be said that there is much in the foregoing pages that is quite out of place in the *Geological Magazine*—much about wind and aqueous vapors, the Nebular Hypothesis and the Unknowable. But is it out of place? If there be any truth in my opening paragraph—that just as an artist has now and again to view his picture from a distance, so does the man of science have from time to time to take a comprehensive survey of his subject—No. In any consideration, however imperfect, of the work which Geology is doing for Modern Philosophy, we must weave that work into the general picture presented by the study of Nature. This I have attempted to do. In the place I have endeavored to point out the law of causation; that all that we see about us has been *caused* in some way or other. In most cases, from the nature of the subject, this law of causation has been illustrated qualitatively; but in the case of the formation of water-vapor the quantitative truth of the law has been indicated; and the law of the conservation of energy briefly alluded to. In the second place I have tried to show, as far as was possible in the space at my command, how the crust of the Earth has been built up by the mechanical agency of rivers, forming deltas, and the vital agency of simply-constituted creatures. By these two agencies nearly all the rocks have been formed, with the exception of salt, and, perhaps, magnesian limestone, which are due to chemical agency. By the action of earth-heat and other causes, however, some of these rocks have been so altered that their original source is scarcely, if at all recognizable. How this earth-heat has raised the strata, thus formed beneath the sea, above the waters of the ocean, has been pointed out; and the action of the sea-waves, and of rain and rivers in carving out the face of the country, horizontally and vertically, has been indicated. In tracing the chain of causation from the well-known to the Unknowable, I have not followed the example set by Prof. Huxley in the excellent little book which bears the same title as this article. In these days, however, when we hear so much of the "pride of Science," it is well to point out that in the study of Nature we reach at last ultimate questions, with respect to which we must one and all confess with modest humility that we are and must be ignorant. Finally, in making each fact the effect of one which had gone before it, in time, and the cause of one which followed, I have aimed at that *organization* of knowledge, without which any number of accumulated facts are but isolated pieces of general information.—*Geological Magazine.*

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RECENT LITERATURE.

Brehm's Animal Life.[1]—The third volume of this interesting series, which is to comprise in all ten large octavo volumes, is at hand, and perhaps the present one is as valuable and entertaining as any, since it treats of the horses and Ruminants, and the seals and Cetacea. There are one hundred and twenty wood-cuts of the same general excellence as those which appear in this notice, and there are besides twenty-one full-page plates; those of the Shetland pony, zebra, ibex, jak, stag, bison, rhinoceros, wild boar and sea lions being especially attractive, and apparently faithful studies by the most eminent German zoölogical artists. Among the wood-cuts the antelopes, elands, spring-bock, hartebeest and their allies, are well rendered. The figures that we have selected are fair examples of the artistic work. The American reader will find that some of the characteristic ruminants of his country are well drawn, as in the Rocky Mountain sheep (Fig. 1), and the musk ox (Fig. 2). The hippopotamus is well drawn, especially its head and face, and its skeleton (Fig. 3.) is represented, while the account of it by Dr. Brehm is detailed and fresh. The

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[1] *Brehm's Thierleben.* Allegemeine Kunde des Thierreichs. Grosse Ausgabe. Zweite umgearbeitete und vermehrte Auflage. Erste Abtheilung. Säugethiere. Dritter Band. Leipzig, 1877, 8vo. For sale by B. Westerman & Co., New York, at 40 cents a part.